INDIRECT ILLUMINATION WITH NITROGEN - FILLED LAMPS

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INDIRECT ILLUMINATION

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A THESIS

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PREFACE

In recent years, the development of illuminating engineering and the demand for illuminating engineers has increased rapidly. People in general, have come, at last, to realize that different classes of work require different forms of illumination. One of the latest accomplishments in this branch of engineering has been the development of the gas-filled bulb in connection with the metallic filament, and more particularly the growth of the nitrogen filled lamp. Owing to the fact that it is only recently that the nitrogen-filled lamps have been put on the market, complete sets of data and complete tests have not as yet been made. The lack of data on this form of lamp led the authors to use this as their thesis, with the results obtained and given in the text.

The authors wish to acknowledge their indebtedness to Professors Freeman and Marsh of the Electrical Department of the Armour Institute of Technology for their valuable suggestions

and assistance in the work. The authors are also under obligations to the Central Electric Co., The Macbeth-Evans Co. and the Gill Electric Co.

May, 1915.

CHAPTER I

Introduction

The study of the physiological requirements for satisfactory illumination has brought to light the shortcomings of the ordinary direct lighting. The harmful effects upon the eyes from the use of artificial exposed light may be divided into three parts. First, the heat effect: Light radiation is a form of energy and upon entering the eye is absorbed and converted into heat. While the power of ordinary illuminants is not sufficient to cause burns, it does cause eye fatigue and serious inflamation. The second harmful effect is due to the strain encountered by the eye when trying to perceive equally well both dark and light objects in a room. The magnitude of the strain on the eye depends upon the position of the light with reference to the eye; but nothing except the removal of the light from the range of vision will relieve the eyes of this strain.

The third harmful effect of exposed lighting is the fatigue due to annoying shadows. If the room is lighted with a single unit, there will be only one deep shadow; but if, as is more often the case, a number of units are distributed throughout the room, the eye is confronted with a multiplicity of light shadows which can not be avoided.

To eliminate these shortcomings of the common methods of illumination, numerous methods have been devised, foremost among which is indirect illumination. The resulting illumination protects the eye from direct heat rays. Since the light source is completely hidden, the pupil of the eye may expand freely, and so easily distinguish all objects equally well. Furthermore, shadows are eliminated to a more marked degree than is possible by any other of the present systems of illumination.

Indirect illumination unfortunately requires scientific planning and designing which is not

essential for direct lighting. With this object in view, a series of tests were carried out with an Alexlite fixture using a nitrogen filled bulb, to ascertain the most advantageous position of the filament with respect to the ceiling and also the position of the bowl with respect to the ceiling.

CHAPTER II

Photometers

In this test, three photometers were used: first, the Lumner-Brodhun photometer; second, the globe photometer and third, the Sharp-Miller photometer.

The Lumner-Brodhun photometer consists of an optical arrangement whereby the two sides of the screen can be viewed at the same tine. A diffusing screen, SS', Fig. I, of high refracting power, is placed with its plane normal to the photometric axis of the bench. The light reflected from the two sides of the screen SS' falls upon the mirrors M_1 and M_2 and is reflected along a normal to the surface of a triangular prism A and B. The observer looking through the telescopic tube O directed normally to B, clearly views a divided field illuminated partly by one source and partly by the other.

The rays from I_1 pass directly through the central part of the prisms illuminating the

central portion of the field. The rays from I_2 pass in the same way into the prism B and constitute the outer portion of the field of view. The paths of the light rays viewed through the eye-piece are indicated by full lines in Figure I. Those shown dotted from I_1 are reflected by the prism B out of the line of vision while those represented by the dotted line from I_2 pass directly through the prisms out of view. With this arrangement one observes a two-part illuminated field as shown at O.

Ulbricht Globe Photometer. One of the simplest and most satisfactory methods of measuring mean spherical intensities is by means of the globe photometer. The determination of the mean spherical candle power of light sources by a single measurement was accomplished by Ulbricht in 1900 after having derived the theorem that any area upon the inner surface of a sphere is illuminated by all other bright patches proportional to their brightness only,

and irrespective of their position.

The globe photometer used was a hollow sphere 120 cm. in diameter. The frame of the globe is made in two hemispheres, being formed of office netting. The interior of the frame is lined with two thin coatings of asbestos, 0.1587 inches thick, one fastened to the netting with small wires and the other placed upon the first and secured to it by a silicon compound. The two hemispheres are rigidly held together by means of metal clamps.

An opening 46.356 cm. in diameter in the upper portion for inserting the lamps and a similar opening near the bottom for repairing the interior surface were provided for. The interior of the sphere was coated with white calcimine. One observation window, covered with a diffusing glass, was provided for, a little below the central horizontal position.

The general theory of the spherical photometer, as given by Dr. Block is as follows.

When a source of light is placed inside a spherical shell having a matt surface, the light received by any part of the interior surface can be considered in two parts, the direct illumination from the light source, and the reflected illumination.

Assume a surface P (Fig. II) to be illuminated by radiation from a small luminous area dA, the brightness of which is B; then the light received on a unit area at P is $\frac{B\ dA\ \cos a\ \cos b}{l^2}$, a and b being the angles which l makes with the normals to the two surfaces. Let (Fig. III) represent a section through the photometer into which is inserted for measurement a lamp L, and consider the illumination of the surface at a point P by light reflected from a small area dA, and the circle shown be a section through the point P and the area dA, then the light received on dA from the lamp directly will be E_A dA, and the $\int E_A\ dA = F$, the total light emitted by the

lamp. The intensity of dA is kE_A since the surface is perfectly matt and throws the light in all directions equally, k being the reflecting constant for the surface. The light received from the surface dA at P once reflected is

$$F_A = \frac{k\ I_A\ dA\ \cos^2 a}{l^2} = \frac{k\ I_A\ dA}{4r^2}$$

Hence the illumination at P due to once reflected light from the whole surface of the sphere will be $\frac{k}{4r^2}\int E_A\ dA = \frac{k}{4r^2}\ F.$

The illumination at P by light twice reflected will be $(\frac{k}{4r^2})^2 F.$

The total illumination at P due to reflected light is $F(k/4r^2 + (k/4r^2)^2 + (k/4r^2)^3 - -) = KF$ where K is the constant of the instrument and depends upon the size of the sphere and the quality of the interior surface.

Thus it can be seen that the illumination of the interior of the sphere is theoretically uniform and proportional to the total light emitted by the lamp; therefore if a small area be screened from the direct rays of the lamp,

the remaining illumination of that area is proportional to the mean spherical candle power of the lamp.

Sharp - Miller Photometer. The Sharp - Millar photometer is the portable photometer most extensively used in this country. In it as embodied the characteristics of an ideal photometer. It has the best method of obtaining a photometric balance; it is portable, simple in operation, and is adaptable as a reliable source of light for a comparison standard. The sensitive photometric device is a modification of the Lumner Brodhun equality of brightness photometer, which is viewed through a collapsible telescopic eye-piece through the side of the box.

The photometrical balance is obtained by looking through the eyepiece and varying the distance between the comparison lamp and the photometric screen. The comparison lamp consists of a tungsten low voltage lamp of the battery type. In circuit with it are placed

an ammeter and a small rheostat for regulating the current. By maintaining the current constant in the standard, the intensity is kept at the proper value.

The light from the comparison lamp falls upon a milk glass plate which is viewed through the eyepiece. The intensity of the light upon this plate is made to vary inversely as the square of the distance from the comparison source by making the inside of the box black and interposing a system of moving black screens which prevent any light from falling upon the plate except that which comes from the comparison source.

The scale upon which the readings are indicated is made of translucent celluloid and is illuminated by means of a small slit in the housing of the comparison lamp so that it may be read in dark places without the aid of other light. The scale is graduated with an inverse-square scale and is placed over a longitudinal opening in the side of the box

so that it may be observed from the outside. There is a shutter which may be dropped over the screen so that the observer will not be influenced by previous readings.

The elbow tube at the end of the box is fitted friction-tight on a collar so that it may be rotated through any angle about a horizontal axis. The angle is indicated by means of a pointer on the elbow and a semi-circular scale upon the box. The tube furnishes the simplest means of measuring illumination or light coming from and direction. A reversible plate is fixed in the elbow of the tube; one side of which may be used in measuring candle power; and the other side, which is a mirror may be used in measuring illumination.

Where intense illumination is to be measured an absorbing plate or screen is inserted between the elbow tube and the screen, thus bringing the illumination on the field to such a value that a balance may be obtained.

CHAPTER III

Preliminary Calculations

Probably the first thing to do in making a test of any kind is to calibrate the instruments to be used. In this test two voltmeters and two ammeters were used. By means of a potentiometer, it was found that one voltmeter read correctly, while the other was four-tenths of a volt high from one hundred volts up to one hundred and twenty volts. The ammeter used in the test was found to read three-hundredths of an ampere low between the limits of the current used in the test.

Having obtained calibrated instruments, the next step is to determine the mean spherical candle-power of the lamp which in this case was a nitrogen-filled, 300-watt tungsten lamp. This is done in the following manner: a calibrated vacuum lamp from the Electrical Testing Laboratory is used as a standard. In order that this lamp shall not be burned for

any great length of time, thus changing its candle power, a secondary standard is obtained. This is done by placing the standard lamp at one end of the photometer bench and the secondary standard at the other end with the photometer head midway between them. With this setting, the voltage on the secondary standard is changed until a balanced condition on the photometer is obtained; its horizontal candle-power in this particular position, and at this particular voltage is now equal to that of the original standard, and may itself be used as a primary standard. In this test, a 220c.p. vacuum lamp (#4577) was used as a primary standard and was to be worked at 110.4 volts and 2.075 amperes. The voltage of the secondary standard to give the same candle-power was found to be 111.24 volts.

The next step is to determine the mean horizontal candle-power (m.h.c.p.) of a lamp whose reduction factor is known. This is determined

The new standard is set at one end of the photometer bench in the proper position, and working at the voltage found (111.24). The comparison lamp is placed at the other end of the bench and is worked at 110 volts. By changing the position of photometer head, a balance can be obtained and the candle-power of the comparison lamp calculated from the equation:

$$I_x = I_o \frac{r_x^2}{r_o^2}, \quad \text{where}$$

I_x = candle-power of comparison lamp

I_o = candle-power of standard lamp

r_x = distance between screen and comparison

r_o = distance between screen and standard

This value having been obtained, the comparison lamp is rotated ten degrees at a time and the candle-power for each position is calculated. The average of the values obtained gives the m.h.c.p. The mean spherical candle-power (m.s.c.p.) is found by multiplying the m.h.c.p. by the reduction factor. The lamp used had a

m.h.c.p. of 210, and a reduction factor of .78. This gave the m.s.c.p. as 164.

To calibrate the globe photometer now is a simple matter. The lamp with the known m.s.c.p. is placed inside the globe and the Sharp-Millar photometer is set to read the m.s.c.p. directly. The voltage on the Sharp-Millar is then adjusted until the illumination on the screen is balanced. Thus a direct-reading photometer for m.s.c.p. is obtained, providing, of course, that the Sharp-Miller photometer is worked at the above determined voltage. If the comparison lamp is replaced by a lamp of unknown m.s.c.p. such as the nitrogen lamp, its m.s.c.p. can be directly determined by obtaining a balance on the S-M photometer by moving its lamp to or from the screen. The m.s.c.p. can be read directly from the scale. In the case of the nitrogen lamp, it was found to be 284 c.p.

In expressing the efficiency of a lamp, it has long been the custom to express it as so

many lumens per watt. The reason for this is simple and becomes apparent with a little consideration; with the recent development in shades, reflectors, etc. the h.c.p. has very little to do with the resultant illumination; it is the total number of lumens given off that affects this. The total number of lumens given off is equal to $4\pi \times$ m.s.c.p. It was, therefore, for this lamp $4\pi \times 278 = 3500$ lumens. The number of watts consumed was 269, and its efficiency was, therefore, $\frac{3500}{269} = 13$ lumens per watt.

The lamp is now ready to be put in place and its distribution curve determined. Before doing this, however, it is necessary to calibrate the Sharp-Miller photometer, so that it will read foot-candles illumination directly. This is done in the following manner: A standard 32 c.p. lamp was used and placed at such a distance away that there was an illumination of one foot-candle on the photometer. This distance was determined from the

equation:

$$E = \frac{I}{r^2} \quad \text{and} \quad r = \sqrt{\frac{I}{E}}$$

$I = 32$ c.p. $\quad E = 1$ ft. candle

$r = \sqrt{32} = 5.66'$

The scale on the photometer was then set to read 1 ft. candle and a balance was obtained by adjusting the voltage to the proper value. If for any value of illumination, this current is kept at the above value and the photometer lamp is adjusted to a balance, the scale will read the foot-candles illumination directly. For very low illumination, the photometer lamp is too bright and a screen must be used. The screen used in this case was found to multiply the actual illumination by 18.74; i.e., the scale reading must be divided by 18.74 to get the true illumination.

CHAPTER IV

Actual Work and Results

The main purpose of this test was to determine the proper relation of the ceiling, lamp and bowl with respect to each other. To do this, a series of runs were made for different positions and the distribution curves plotted. The stations or points of measurement were three feet apart to a distance of twenty-one feet. A group of data was taken under the following conditions: the size of the ceiling was fixed at 6' 0" x 6' 0"; second, the distance between the ceiling and lamp was fixed; and third, six positions of the bowl with respect to the ceiling were used and curves plotted. This set of data comprises the group of curves given on Chart #I. Similar groups of curves were plotted for seven other distances between the lamp and the ceiling, and the results plotted and given in Charts #1 to #8 inclusive. A similar set

of data, as above mentioned, was taken for a smaller ceiling which was 4' 3" in diameter. The results obtained were plotted and are given in Charts #1_a to #7_a inclusive.

A secondary purpose of this test was to determine the distribution curves of several enclosing globes for nitrogen lamps and to determine the absorption coefficient of each. Three enclosed globes were used, one from the Macbeth Co. and two acorns of different size from the Gill Co. A distribution curve was also taken for an X-Ray reflector. These curves are all given on Chart A. To determine the absorption coefficient, the bare lamp was placed inside the globe potentiometer and the Sharp-Millar photometer was read. The enclosing globe was then placed over the lamp and the photometer read again. The ratio of these two readings gave the percent light transmitted, and 100% minus this gave the absorption coefficients. These latter tests were made with a 200-watt

nitrogen lamp.

A summary of the important facts relating to this test is given below.

Best position of lamp and bowl with respect to 6' 0" ceiling	Lamp 21 " below ceiling Bowl 23.75" " "
Best position of lamp and bowl with respect to 4' 3" ceiling	Lamp 14.5"below ceiling Bowl 17.25" " "

Absorption Coefficient of Macbeth globe = 15.6%

" " " Gill large acorn = 21.9%

" " " " small " = 27.5%

M.H.C.P. of SECONDARY STANDARD.

Scale Reading	Degrees	Scale Reading	Degrees	Scale Reading	Degrees	Scale Reading	Degrees	Scale Reading	Degrees
126.8	0	126.6	80	125.7	160	125.9	240	125.7	320
125.8	10	126.8	90	126.7	170	126.8	250	129.4	330
126.4	20	125.9	100	125.7	180	125.7	260	126.0	340
128.0	30	126.6	110	126.6	190	127.8	270	126.4	350
125.8	40	127.5	120	126.1	200	126.8	280	126.6	360
126.9	50	125.6	130	125.5	210	125.7	290		
126.3	60	126.6	140	126.5	220	126.5	300		
126.3	70	127.4	150	125.7	230	125.6	310		

M.H.C.P. = 210.4
M.S.C.P. = 164.0

M.S.C.P. of 300 watt nitrogen-filled bulb = 277.9

Volts = 110.

Amperes = 2.45

Efficiency = 12.98 lumens per watt.

M.S.C.P. of 200 watt nitrogen-filled bulb = 279.8

Volts = 115.

Amperes = 1.975

Efficiency = 15.40 lumens per watt.

FT.-CANDLE ILLUMINATION ON PLANE 13 FT. FROM REFLECTING SURFACE, (6'x6').

300 WATT NITROGEN-FILLED BULB WITH INDIRECT FIXTURE.

DISTANCE FROM CEILING TO		STATIONS, (3' APART).							
BOTTOM OF BOWL	CENTER OF FILAMENT	1	2	3	4	5	6	7	8
23.75"	21"	2.34	2.13	1.73	1.05	0.61	0.32	0.19	0.12
24.25"		2.18	2.00	1.51	1.03	0.61	0.32	0.19	0.12
24.875"		2.05	1.89	1.40	0.93	0.53	0.32	0.18	0.12
25.5"		1.95	1.75	1.30	0.84	0.48	0.28	0.17	0.10
26.15"		1.95	1.71	1.19	0.68	0.36	0.26	0.17	0.10
26.75"		1.66	1.58	1.18	0.72	0.34	0.24	0.15	0.09
23.25"	20.5"	2.19	2.02	1.42	0.94	0.53	0.30	0.17	0.11
23.75"		2.10	1.86	1.36	0.85	0.53	0.27	0.17	0.11
24.375"		1.99	1.77	1.36	0.73	0.49	0.28	0.18	0.10
25.0"		2.05	1.78	1.36	0.73	0.49	0.28	0.16	0.10
25.65"		2.06	1.81	1.24	0.82	0.46	0.28	0.16	0.10
26.25"		1.84	1.61	1.22	0.77	0.45	0.27	0.15	0.09
22.25"	19.5"	2.27	1.93	1.53	0.94	0.56	0.34	0.19	0.12
22.75"		2.14	1.91	1.43	0.92	0.49	0.31	0.18	0.11
23.375"		2.12	1.75	1.40	0.89	0.49	0.28	0.17	0.10
24.0"		2.01	1.82	1.33	0.86	0.44	0.28	0.17	0.10
24.65"		1.93	1.61	1.29	0.75	0.46	0.26	0.16	0.10
25.25"		1.87	1.67	1.17	0.74	0.43	0.25	0.15	0.09
21.25"	18.5"	2.26	1.95	1.58	0.97	0.54	0.31	0.20	0.12
21.75"		2.15	1.97	1.49	0.94	0.52	0.30	0.18	0.11
22.375"		2.15	1.90	1.31	0.86	0.50	0.29	0.18	0.11
23.0"		2.06	1.84	1.33	0.90	0.48	0.29	0.15	0.11
23.65"		2.03	1.74	1.30	0.85	0.49	0.29	0.17	0.11
24.25"		1.82	1.76	1.24	0.81	0.43	0.27	0.16	0.11

DATA SHEET NO. 2.

FT-CANDLE ILLUMINATION ON PLANE 13 FT. FROM REFLECTING SURFACE (6'x6').

300 WATT NITROGEN-FILLED BULB WITH INDIRECT FIXTURE.

DISTANCE FROM CEILING TO		STATIONS, (3' APART).							
BOTTOM OF BOWL	CENTER OF FILAMENT	1	2	3	4	5	6	7	8
20.25"	17.5"	2.13	1.99	1.49	0.99	0.50	0.32	0.19	0.13
20.75"		2.08	1.99	1.49	0.96	0.49	0.30	0.19	0.13
21.375"		2.15	1.99	1.50	0.95	0.51	0.30	0.17	0.13
22.0"		2.08	1.90	1.26	0.77	0.43	0.25	0.14	0.09
22.65"		1.96	1.66	1.23	0.74	0.40	0.25	0.17	0.10
23.25"		1.85	1.66	1.23	0.74	0.40	0.23	0.15	0.09
19.25"	16.5"	2.20	2.05	1.55	0.94	0.53	0.33	0.18	0.11
19.75"		2.23	2.06	1.46	0.92	0.50	0.32	0.19	0.13
20.375"		2.11	1.97	1.34	0.86	0.49	0.28	0.17	0.11
21.0"		1.97	1.78	1.24	0.76	0.46	0.28	0.14	0.10
21.65"		1.83	1.65	1.20	0.73	0.43	0.26	0.15	0.09
22.25"		1.89	1.63	1.18	0.79	0.41	0.26	0.15	0.10
18.25"	15.5"	2.24	2.09	1.52	0.91	0.53	0.32	0.20	0.12
18.75"		2.11	2.00	1.41	0.88	0.52	0.30	0.18	0.10
19.375"		2.02	1.88	1.44	0.92	0.51	0.28	0.18	0.10
20.0"		1.99	1.83	1.31	0.88	0.45	0.27	0.17	0.10
20.65"		1.93	1.77	1.34	0.87	0.49	0.29	0.18	0.12
21.25"		1.99	1.83	1.34	0.90	0.50	0.30	0.17	0.11
17.25"	14.5"	2.37	2.13	1.52	1.00	0.53	0.34	0.19	0.12
17.75"		2.23	2.02	1.48	1.01	0.52	0.33	0.20	0.13
18.375"		2.18	1.98	1.50	1.00	0.52	0.32	0.20	0.12
19.0"		2.19	1.99	1.42	0.93	0.49	0.31	0.19	0.11
19.65"		2.06	2.00	1.44	0.90	0.49	0.31	0.19	0.12
20.25"		1.92	1.72	1.26	0.86	0.46	0.29	0.16	0.11

FT.-CANDLE ILLUMINATION ON PLANE 13 FT. FROM REFLECTING SURFACE, (DIAM. 4.25').
300 WATT NITROGEN-FILLED BULB WITH INDIRECT FIXTURE.

DISTANCE FROM CEILING TO		STATIONS (3' apart).							
BOTTOM OF BOWL	CENTER OF FILAMENT	1	2	3	4	5	6	7	8
23.25"	20.5"	1.40	1.35	1.03	0.61	0.38	0.22	0.12	0.09
23.75"		1.31	1.28	0.96	0.55	0.35	0.21	0.12	0.09
24.375"		1.33	1.25	0.90	0.54	0.32	0.21	0.12	0.09
25.0"		1.26	1.23	0.90	0.54	0.35	0.21	0.12	0.08
25.65"		1.26	1.23	0.88	0.53	0.32	0.19	0.12	0.08
26.25"		1.23	1.12	0.84	0.50	0.30	0.19	0.12	0.07
22.25"	19.5"	1.38	1.33	0.95	0.56	0.35	0.24	0.14	0.08
22.75"		1.34	1.25	0.92	0.54	0.31	0.21	0.13	0.08
23.375"		1.34	1.26	0.96	0.54	0.34	0.22	0.13	0.08
24.0"		1.33	1.22	0.94	0.53	0.34	0.21	0.12	0.09
24.65"		1.29	1.26	0.96	0.54	0.34	0.22	0.12	0.08
25.25"		1.31	1.13	0.91	0.53	0.31	0.21	0.12	0.08
21.25"	18.5"	1.65	1.44	1.13	0.71	0.38	0.24	0.16	0.09
21.75"		1.64	1.42	1.09	0.70	0.37	0.23	0.14	0.08
22.375"		1.45	1.34	0.95	0.68	0.36	0.23	0.14	0.08
23.0"		1.35	1.17	0.93	0.54	0.32	0.21	0.14	0.08
23.65"		1.31	1.13	0.93	0.54	0.33	0.21	0.12	0.08
24.25"		1.31	1.14	0.90	0.52	0.34	0.20	0.13	0.08
20.25"	17.5"	1.61	1.45	1.13	0.72	0.41	0.24	0.15	0.08
20.75"		1.53	1.39	1.09	0.69	0.39	0.23	0.14	0.08
21.375"		1.51	1.41	1.04	0.65	0.37	0.23	0.14	0.08
22.0"		1.32	1.23	0.97	0.62	0.33	0.19	0.12	0.07
22.65"		1.35	1.25	0.94	0.60	0.33	0.21	0.13	0.07
23.25"		1.34	1.18	0.87	0.56	0.32	0.21	0.12	0.07

DATA SHEET NO. 4

FT.-CANDLE ILLUMINATION ON PLANE 13 FT. FROM REFLECTING SURFACE (DIAM. 4.25').

300 WATT NITROGEN-FILLED BULB WITH INDIRECT FIXTURE.

DISTANCE FROM CEILING TO		STATIONS (3' apart).							
BOTTOM OF BOWL	CENTER OF FILAMENT	1	2	3	4	5	6	7	8
19.25"	16.5"	1.53	1.41	1.01	0.66	0.34	0.22	0.13	0.09
19.75'		1.46	1.30	1.00	0.62	0.32	0.20	0.13	0.08
20.375"		1.38	1.23	0.95	0.60	0.33	0.22	0.13	0.08
21.0"		1.32	1.19	0.93	0.62	0.32	0.21	0.13	0.08
21.65"		1.31	1.18	0.89	0.56	0.33	0.19	0.13	0.08
22.25"		1.21	1.09	0.84	0.54	0.30	0.18	0.12	0.07
18.25"	15.5"	1.91	1.79	1.31	0.77	0.40	0.24	0.15	0.08
18.75"		1.69	1.50	1.16	0.69	0.39	0.22	0.13	0.09
19.375"		1.73	1.52	1.14	0.71	0.39	0.22	0.15	0.09
20.0"		1.79	1.50	1.15	0.68	0.37	0.23	0.14	0.09
20.65"		1.51	1.38	1.13	0.62	0.35	0.20	0.14	0.08
21.25"		1.56	1.47	1.16	0.71	0.40	0.24	0.15	0.09
17.25"	14.5"	1.88	1.81	1.26	0.91	0.49	0.27	0.17	0.12
17.75"		1.94	1.72	1.22	0.83	0.43	0.25	0.15	0.10
18.375"		1.71	1.54	1.15	0.77	0.41	0.26	0.15	0.10
19.0"		1.57	1.38	1.12	0.70	0.39	0.25	0.14	0.10
19.65"		1.52	1.41	1.02	0.70	0.36	0.22	0.14	0.09
20.25"		1.42	1.31	1.01	0.70	0.35	0.20	0.14	0.08

FT.-CANDLE ILLUMINATION ON PLANE 14 FT. FROM CEILING.

200 WATT NITROGEN-FILLED LAMP WITH DIFFERENT ENCLOSING GLOBES.

CENTER OF GLOBES 2 FT. FROM CEILING.

MACBETH

STATIONS	1	2	3	4	5	6	7	8
FT.-CANDLES	3.04	1.95	1.62	1.00	0.61	0.42	0.27	0.18

200 WATT ACORN

STATIONS	1	2	3	4	5	6	7	8
FT.-CANDLES	2.14	1.88	1.36	0.85	0.53	0.31	0.21	0.13

100 WATT ACORN

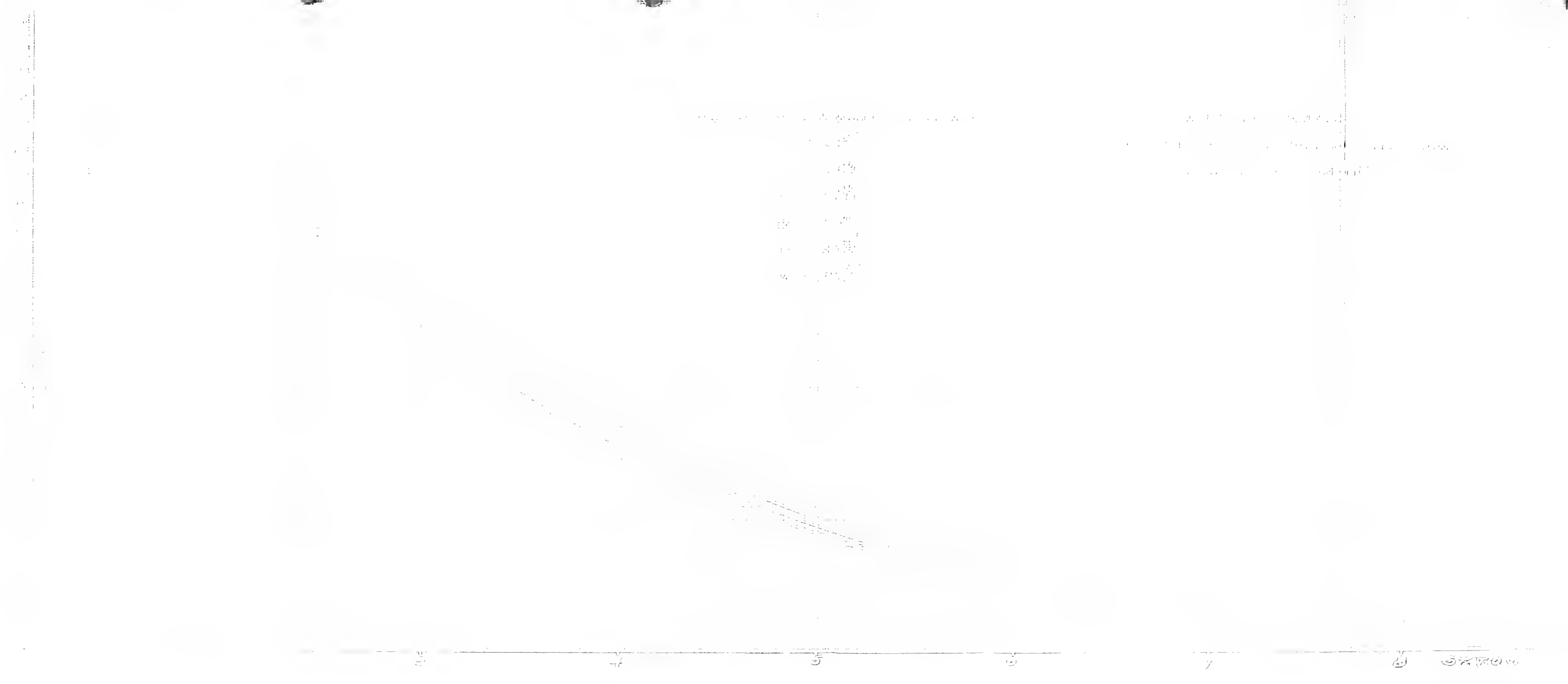
STATIONS	1	2	3	4	5	6	7	8
FT.-CANDLES	2.33	2.03	1.55	1.05	0.61	0.39	0.25	0.17

X-RAY REFLECTOR WITH 100 WATT VACUUM BULB.

STATIONS	1	2	3	4	5	6	7	8
FT.-CANDLES	0.38	0.46	0.63	0.53	0.41	0.24	0.18	0.09

ABSORPTION COEFFICIENTS

	BARE BULB	Bulb enclosed by Macbeth globe	Bulb enclosed by 200 watt Acorn	Bulb enclosed by 100 watt Acorn
M.S.C.P.	200	168.8	156.3	145.0
% Absorption		15.6 %	21.9 %	27.5 %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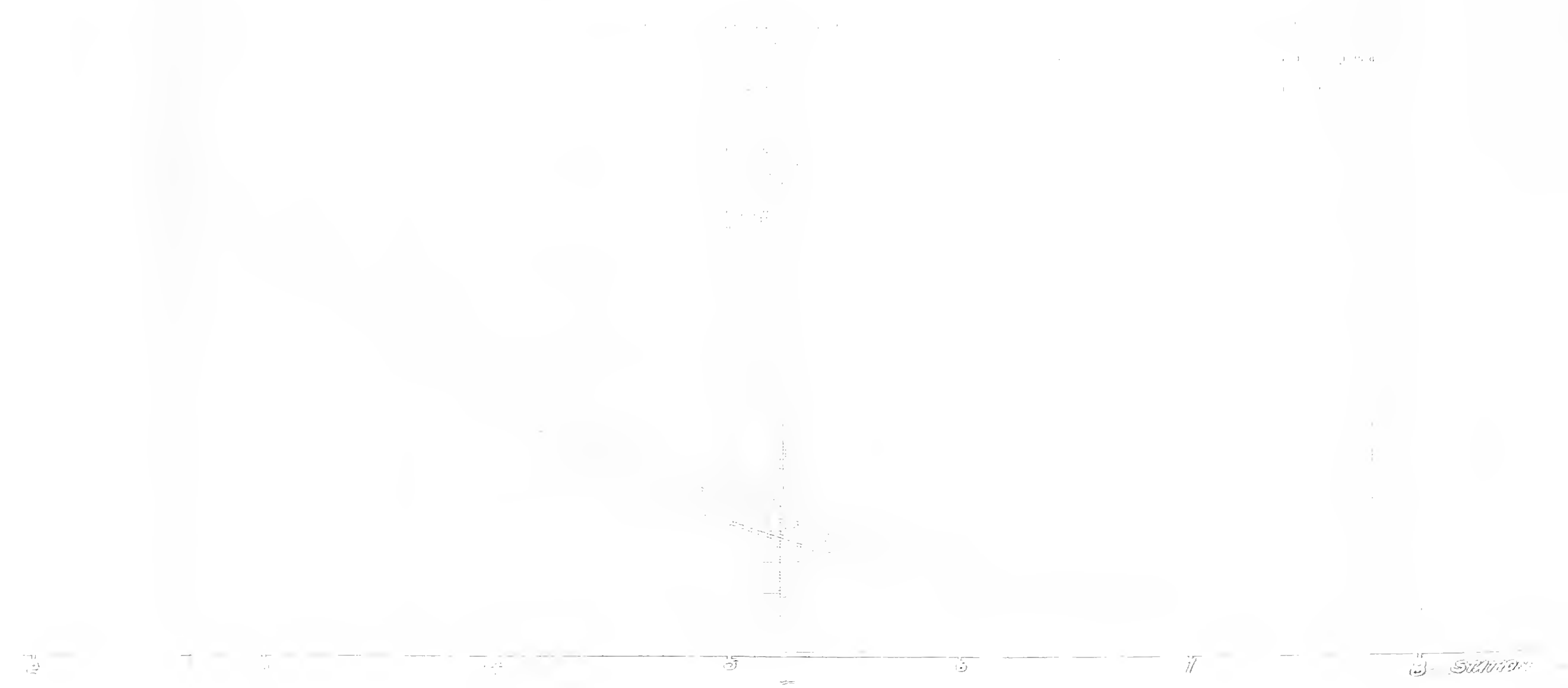

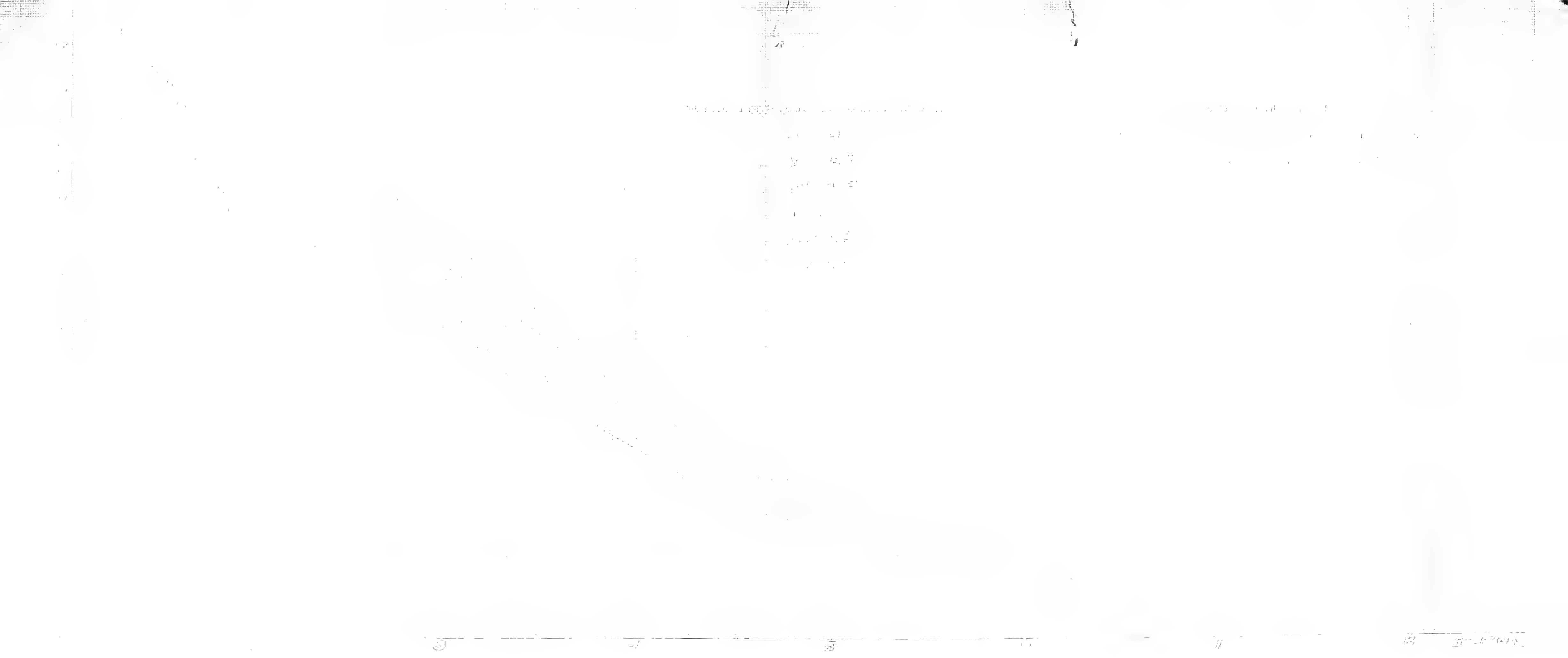


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